MEASURES OF SOLAR OSCILLATIONS AND SUPERGRANULATION BY THE MAGNETIC-OPTICAL FILTER

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Helioseismology is the branch of the Solar Physics which studies the solar global oscillations, a phenomenon very important in order to understand the inside of the Sun. We explain here a method for measuring the solar velocity fields along the line of sight by the VAMOS instrument developed at the Astronomical Observatory of Capodimonte in Naples, in particular we present the measures of the so called five-minutes oscillations and of the Supergranulation

Helioseismology is the branch of the Solar Physics which studies the solar global oscillations. From the power spectrum we can obtain informations about the solar inside, for example the convective zone's depth, the inner layers' rotation velocities, the temperature, the density and the chemical composition. The success of Helioseismology has carried this branch to be extended to analogous studies in other stars (Asteroseismology). An important role in this branch is played by the VAMOS (Velocity And Magnetic Observations of the Sun) project, developed in Naples, at the Astronomical Observatory of Capodimonte. The employed instrument allows us to scan solar photosphere's images in intensity, velocity field and magnetic field along the line of sight; in our work, we used the second type of images.

The VAMOS instrument is composed essentially of a Magnetic-Optical Filter (MOF) and a Wing Selector (WS). MOF consists of a potassium vapours cell with a magnetic field (about 1400 G) along its optic axis, interposed between two crossed linear polarizers. In order to understand how this works, we have to recall the Zeeman effect. Let's consider the atomic transition from the level with $l = 1$ to that with $l = 0$ (where l is the angular momentum quantum number): in absence of magnetic field, there is only an emission line. If we are in presence of a magnetic field, the degeneration of the level with $l = 1$ is removed bringing to three different states with three different values of the atomic quantum number m (magnetic moment

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quantum number) and we can see no more *one* emission line, but *three* emission lines characterized by different states of polarization. In fact two of these emission lines are circularly polarized, respectively right-handed (σ^+) and left-handed (σ^-), around the magnetic field direction, the other (π) is linearly polarized along the magnetic field, so, when we observe along this direction (it's our case) we can't see this last component. MOF is based on two effects: the Righi Effect and the Macaluso-Corbino Effect. Righi Effect is Zeeman effect in absorption: solar light (not polarized) arrives on the first polarizer which transforms it in linearly polarized light (let's recall that linearly polarized light can be viewed as half right circularly polarized and half left circularly polarized); then the cell absorbs half of the light intensity at σ^+ and σ^- wavelengths and the second polarizer cuts half of the light intensity at σ^+ and σ^- wavelengths and cuts totally the other wavelengths. So, at the output, we should see only two peaks at the Zeeman wavelengths, but the net output of the filter is characterized by the presence of the Macaluso-Corbino Effect, too. This consists in a rotation of the polarization plane caused by a difference in refraction index values at the two Zeeman wavelengths in the cell. Higher is the temperature of the cell, stronger is the Macaluso-Corbino Effect which shows itself as two additional symmetric peaks, the distance between which increases linearly with temperature (in the range considered in our work).

WS is positioned after MOF and its role is to select only one of the two MOF output lines. It is composed by a quarter-wave plate and a cell analogous to MOF's cell. If the plate's transmission axis forms with the optic axis an angle of 45 degrees, light's polarization becomes right circular and so the cell cuts the σ^+ component, while leaves the σ^- one to pass; if the plate's transmission axis forms with the optic axis an angle of -45 degrees, we have the opposite situation and only the σ^- component passes.

A velocity image of the Sun is called *dopplergram.* There are many contributes in a dopplergram: some vary very slowly during an observation time (15-20 minutes) and so they can be considered constant, other, instead, vary faster. Contributes that we considered constant are caused by Earth's proper motions (revolution and rotation), solar rotation and gravitational redshift. Instead, contributes quickly variable are due to solar oscillations, granulation, supergranulation and noise. Except the noise, we wanted to measure these. In reality, we have obtained estimations of solar oscillations and supergranulation's velocity, but not of granulation's one because VAMOS spatial resolution doesn't allow to observe this phenomenon.

Solar oscillations (or *five minutes* oscillations) were observed for the first time by Leighton in 1962, but the first theoretical models, in agreement with observations, were developed in the 70's. These oscillations are mainly vertical (so more visible towards the center of the solar image), have an amplitude of 500 m/s, periods of about five minutes and lifetimes that vary from few hours to months. Five minutes oscillations are due to wave propagating under the photosphere. There are essentially two types of waves: acoustic waves (p-modes), generated by pressure variations caused by convective instabilities, and gravity waves (g-modes), transversal, caused by gas' stratification and generated where there are density discontinuities. Gravity waves aren't directly observable, except surface waves (f-modes), propagating in the low photosphere. To measure five minutes oscillations, we considered two dopplergrams, obtained at a temporal interval of two minutes and half (half period). Semidifference between the two dopplergrams gives us the maximum amplitude of solar oscillations. We repeated this proceeding for other two images and then we obtained an average, the *difference-dopplergram*, which gives us, with a good estimation, the five minutes oscillations' profile.

Supergranulation is the photospherical evidence of the Solar convection. Supergrains are 35 times bigger than grains (and so we can observe them with the VAMOS spatial resolution), their mean lifetime is one day and velocities, in this case prevalently horizontal, go from 300 to 500 m/s. To measure supergranulation, we considered once again two dopplergrams obtained at a temporal interval of two minutes and half, but in this case we did a semisum rather than a semidifference: in fact, in this way, we excluded the solar oscillations' contributes. The remaining contributes are due to supergranulation and constant motions. We obtained constant motions spatially smoothing the *sum-dopplergram* image; indeed, by subtracting the smoothed dopplergram to the former, we could obtain the dopplergram relative to the supergranulation.

All the operations on dopplergrams have been made using the IDL program language.